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14. ABSTRACT

We have acquired a custom REMUS Autonomous Underwater Vehicle for use in coastal and shelfbreak environments. During the past two years, we have operated the vehicle in a wide variety of oceanographic settings including the shelfbreak off New Jersey and New England, the Arctic coast near Barrow Alaska, Glover's Reef off Belize, and Vineyard Sound, Massachusetts.

The vehicle capabilities have been enhanced to include an Inertial Navigation System, GPS/Iridium communications, and a SeaBird CTD. We have recently completed a study of cooling of a coastal current east of Cape Cod in winter and two manuscripts will result from this work. The vehicle was also used in the AWACS experiments off New Jersey and New England, providing the first deployment of an AUV in the shelfbreak front.

15. SUBJECT TERMS

REMUS AUV, coastal and shelfbreak environments, shelfbreak front, Inertial Navigation System, GPS/Iridium communications, SeaBird CTD

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Autonomous Underwater Vehicle (AUV) for the study of Coastal and Upper Ocean Processes at the Woods Hole Oceanographic Institution

Final Report

ONR Grant No. N00014-04-1-0631

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Long-term Goals

The long-term goal was to obtain, use and modify a REMUS AUV for use in coastal, shelfbreak, and upper ocean oceanographic applications. We specifically wanted to use the vehicle in conditions which preclude the use of navigational beacons and ADCP bottom tracking such as shelfbreak environments.

Objectives

The primary objective was to obtain and apply a custom AUV for the study of physical oceanographic processes in a variety of coastal and shelfbreak settings to provide new techniques for measuring important features such as shelfbreak fronts and coastal currents. We also planned to use the vehicle in experiments in which there were concurrent acoustic measurements.

Approach

We used the vehicle in a series of experiments in a wide variety of oceanographic settings. Initially, the vehicle was used to study dense water formation during winter east of Cape Cod. It has been used to study coastal currents near Barrow Alaska, evaluate hydrography surrounding a sand ridge in Vineyard Sound, and measure bathymetry and map a coral reef off the coast of Belize. The vehicle was also used in a series off cruises along the shelfbreak off New Jersey and New England. This was the first deployment of an AUV in the shelfbreak front, demonstrating the vehicle's capability in regions with strong currents and a high degree of variability. Results from a number of our deployments have been used to improve control algorithms for the vehicle as we have had many novel applications. Key elements of the vehicle for applications include a

SeaBird CTD mounted beneath the vehicle, an Inertial Navigation System, a Global Positioning System for accurate navigation at the surface and a satellite Iridium communication system (Figure 1)

Tasks Completed

The vehicle was initially used in harsh conditions during winter east of Cape Cod. Using the R/V Tioga, a small coastal vessel, we successfully sampled cross-shelf hydrographic sections showing the structure of the coastal current and its response to cooling and wind forcing. Next, the AUV was successfully deployed from the R/V Tioga at the shelfbreak off New Jersey as part of a pilot study in the area where the Shallow Water Acoustics 06 and Non-Linear Internal Wave Initiative studies took place the following year. The AUV was successfully deployed as part of an AUV cluster off New England in May, 2007 as part of the Advanced Wide Aperture Cluster for Surveillance (AWACS) program. The AUV was operated in the core of the shelfbreak jet.

Results

We have operated the vehicle for three successive winters east of Cape Cod. We found that there was a persistent coastal current which remained throughout the winter, with typical maximum jet velocities of 30 cm/s. The coastal current was strongly affected by wind forcing, with winds from the north accelerating the flow and winds from the southwest driving buoyant water offshore in the surface layer. We have calculated both fresh water and volume transports from the coastal current and found that the fresh water transport is small until March, however, the mean volume transport is large (0.14 m3/s-1) during the winter, accounting for a third of the overall long-term shelf water transport in the Middle Atlantic Bight, further downstream. We have submitted one paper describing the coastal current structure (Shcherbina and Gawarkiewicz, 2007a) and have a second paper in preparation describing the impact of the coastal current on cross-shelf structure of cooling and buoyancy loss (Shcherbina and Gawarkiewicz, 2007b). A figure showing the three-dimensional coastal current structure in March, 2006 appears in Figure 2.

During the summer of 2005, we operated the vehicle along the 80 m isobath to look at alongshelf variability near the foot of the shelfbreak front. P. Abbot and others from OASIS Inc. operated mobile acoustic sources and sonobuoys at the same time and measured transmission loss along the 80 m isobath at the same time. The REMUS was also operated in May, 2007 within the shelfbreak front jet (Figure 3). We successfully measured the frontal structure and velocities during concurrent Mobile Acoustic Source and sonobuoy operations. Analysis of the shelfbreak observations is continuing at the present time.

Impact for Science

We have successfully used a REMUS AUV as part of physical oceanography and ocean acoustics studies in a wide variety of coastal and shelfbreak environments. During the course of the work, we have coordinated our efforts with the Oceanographic Systems

Laboratory at WHOI and used our results to motivate improvement of the control systems of the vehicle to enhance sampling in deep-water environments with strong currents. The Inertial Navigation System has been used to study vehicle performance in these environments. The results from our work with the vehicle will be useful in both basic research on coastal and shelfbreak ocean processes but also in both configuring vehicles and planning operations for clusters of vehicles in joint oceanographic/acoustic experiments.

Relationships to Other Programs

The Physical Oceanography REMUS was used to do pilot studies for the AWACS, NLIWI, and SW06 joint experiments off New Jersey in July-September 2006. It has also been used extensively in the AWACS program which uses AUV clusters for acoustic surveillance. We have also had extensive contacts with Taiwanese engineers and scientists including joint field demonstrations to inform them about REMUS capabilities for studying oceanographic processes.

Figures

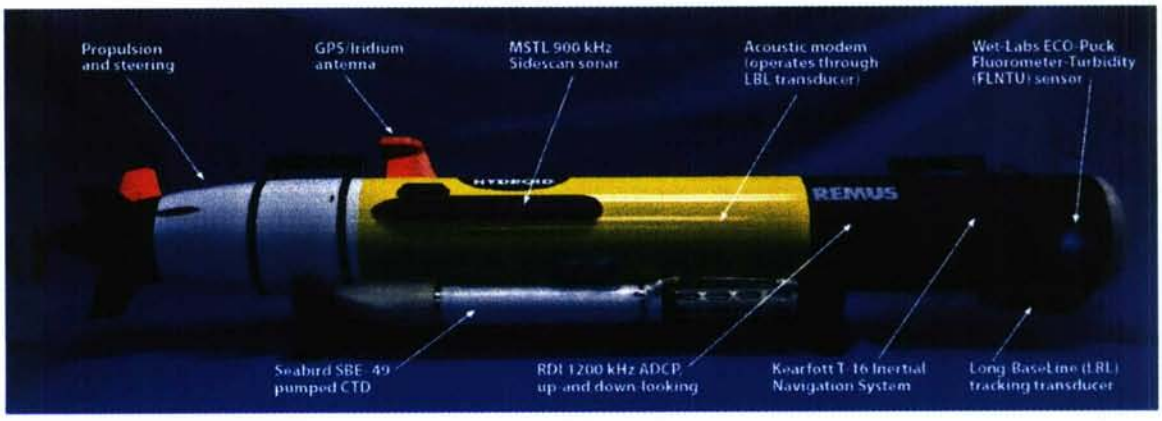

Figure 1- The Physical Oceanography REMUS at WHOI. The vehicle includes an inertial navigation system, a SeaBird CTD, as well as sidescan sonar and GPS/Iridium for navigation and communications.

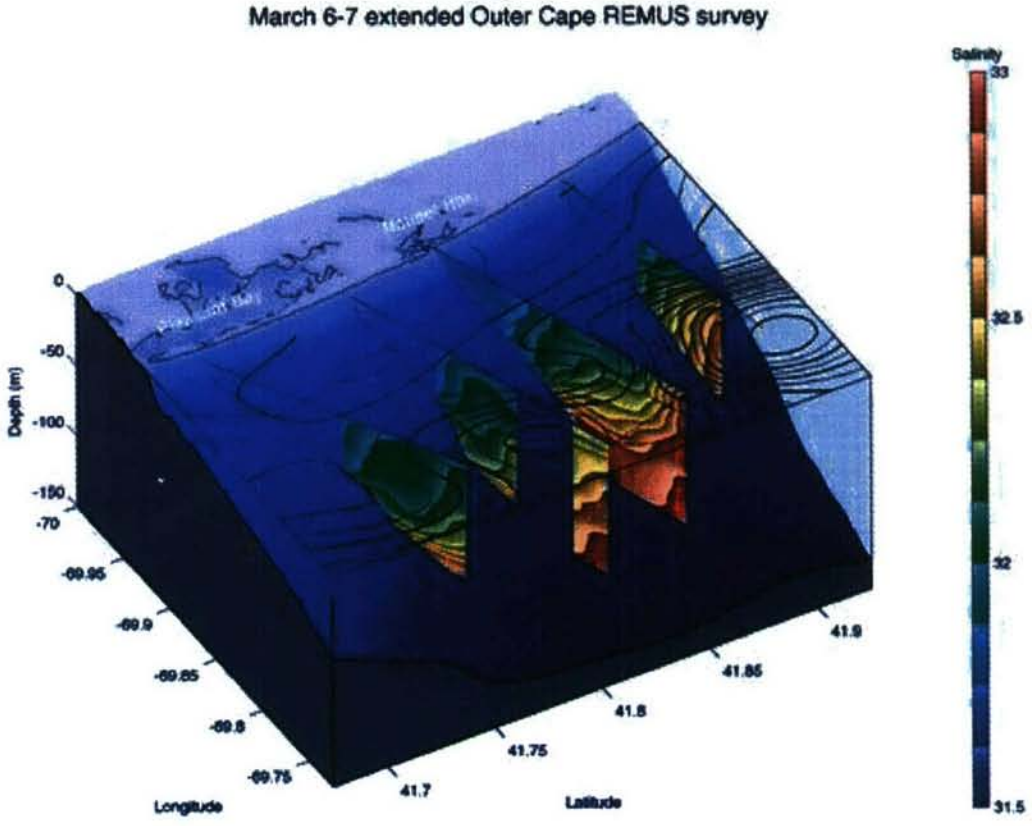

Figure 2- Results from a two-day survey east of Cape Cod, March 6-7, 2006. The salinity field is shown from the cross-shelf REMUS transects. The contours at the surface are measurements from the thermosalinograph on the R/V Tioga

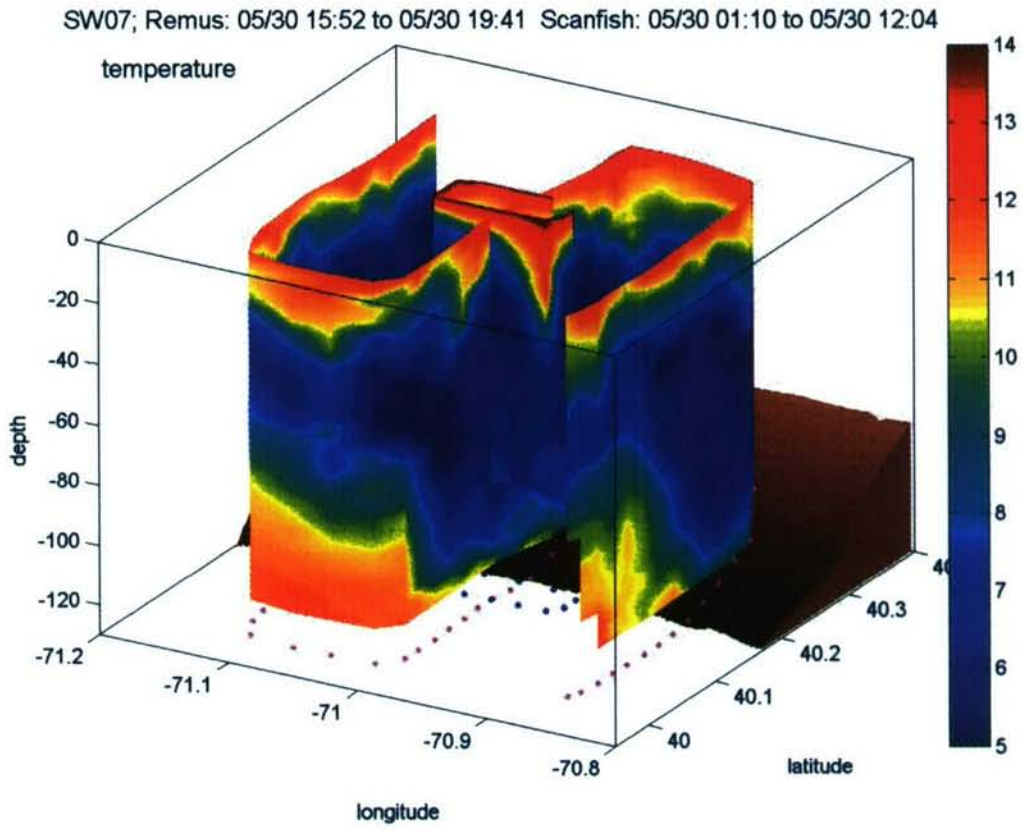

Figure 3: Temperature fields from a combined REMUS/Scanfish survey in the shelfbreak front south of New England. The three cross-shelf transects were sampled with a towed Scanfish, while the along-isobath section in the center was sampled with the REMUS AUV. Note the shelfbreak front, near the offshore edge of the section, and the large amplitude internal waves present in the seasonal thermocline at 20 m depth.

References

Shcherbina, A., and G. Gawarkiewicz, 2007a: A coastal current in winter: Part I: Autonomous Underwater Vehicle observations of the Coastal Current east of Cape Cod. Submitted, J. Geophys. Res.-Oceans.

Shcherbina, A., and G. Gawarkiewicz, 2007b: A coastal current in winter. Part II: Wind forcing and cooling of the Coastal Current east of Cape Cod. To be submitted to J. Geophys. Res.-Oceans.